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Electrochemical characterization of hydrogen pump with internal humidifier and dead-end anode channel

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Hydrogen energy society, especially hydrogen gas station for FCV, needs stable supply of high pressure hydrogen gas at 40 MPa or more than that. However, conventional booster, which is mechanically driven, has rather low reliability and efficiency. Against this situation we expect electrochemical booster called as hydrogen pump, where hydrogen gas is pressurized by the immigration of the gas from anode to cathode through DC-applied MEA (membrane electrode assembly). The hydrogen pump is predicted to have high reliability because of no mechanical links, and it is expected to have high efficiency in principle because of isothermal process. A prototype model of hydrogen pump is designed and fabricated so that it can pressurize hydrogen gas from 0.1 to 2 MPa. An internal humidifier and dead-end at anode are built in this hydrogen pump. In addition to the evaluation of voltage and current efficiency of the hydrogen pump, electrochemical characterizations are done to understand the overvoltage inherently involved in hydrogen pumps.

Figure 1 is the schema of the hydrogen pump cell designed, whose electrode area is 5.3 cm^2. Although the structure of the hydrogen pump is similar to PEFCs, a SUS sintered body is utilized as anode GDL to sustain the differential pressure of 2 MPa between anode and cathode. In addition, an internal humidifier is built in the cell. Water layer shown in cathode separator has the role to wet PEM. Moreover, dead-end type of channel is designed in anode separator, in hopes of no recirculation piping. These designs of the internal humidifier and dead-end of anode will reduce cost of system to operate hydrogen pump cell in its commercialization.

Figure 2 is an IV characteristic of the hydrogen pump cell under the pressure ratio of 10.5 between anode and cathode. The cell voltage at the load current of 0 corresponds to the Nernst potential to pump the hydrogen gas from anode to cathode. Larger load current and lower operation temperature gave higher cell voltages. In hydrogen pump cells, redox reaction of hydrogen gas progresses in a rapid manner, resulting in small non-Ohmic overvoltage. Thus, cell voltages in hydrogen pump cell can be predicted by counting the Nernst potential and Ohmic overvoltage. This tendency can be seen in the IV characteristic in the case of 333 K. However, that in the case of 293 K does not have this tendency, suggesting that some non-Ohmic overvoltage exists.

Figure 3 is a Nyquist plot obtained in AC impedance measurement under the condition that pressure ratio, operation temperature and frequency region are 10.5, 293 K and 1mHz-20kHz, respectively. Larger load current caused larger arc at low frequency region. Because, in hydrogen pump cell, diffusive hydrogen gas is supplied and discharged, the resistance originated in diffusion process is expected to be small. However, the water layer, which works as humidifier, is thought to be a transport resistance of hydrogen gas, leading to the larger arcs with increase of load current in Fig. 3. This consideration can be supported by the non-linearly-increase of cell voltage shown in Fig.2.

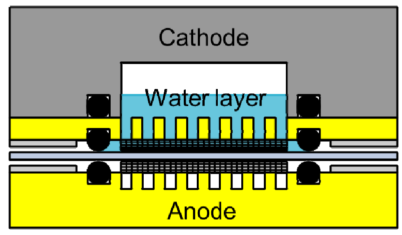

Fig. 1 Schema of developed hydrogen pump cell, in which internal humidifier and dead-end anode channel are built in.

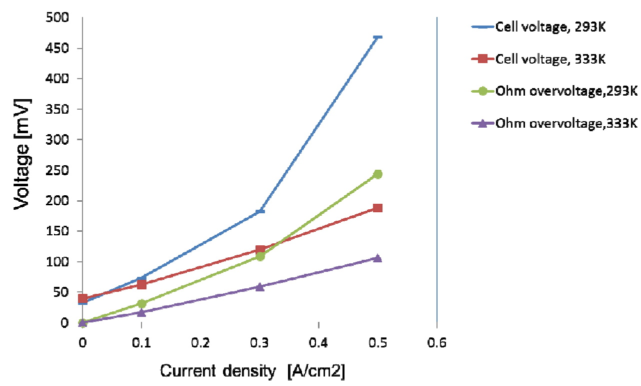

Fig. 2 IV characteristics of the hydrogen pump in the case of 293 K and 333 K under the pressure ratio of 10.5.

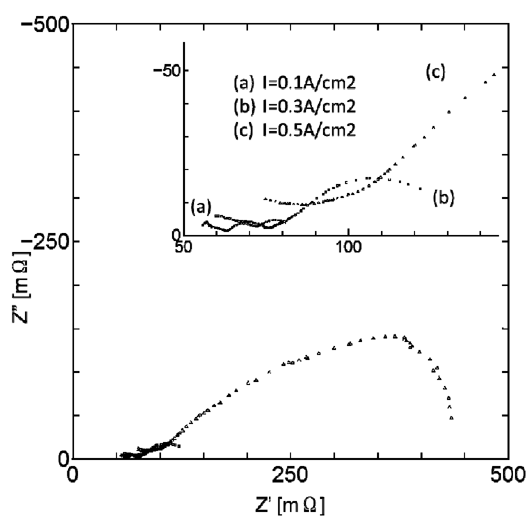

Fig. 3 Nyquist plot obtained by AC measurement in the case of 0.1, 0.2 and 0.5 A/cm2. In the measurement, pressure ratio and operation temperature were 10.5 and 293 K, respectively.